

Mars Sample Return Studies for a Fresh Look

**2002 IEEE Aerospace Conference
March 2002**

**Richard Mattingly
Steve Matousek
Robert Gershman**

**Solar System Exploration Advanced Studies Office
Jet Propulsion Laboratory, California Institute of Technology**



Why These Studies?

- Mars technology Program needs to needed to determine the technology needed my MSR.
- Mars Smart Lander needed to know what MSR capabilities it needed to demonstrate.
- Potential Foreign Partners needed inputs on MSR Architecture to enable their program funding.
- NASA and JPL needed to know a current potential cost of MSR; some previous assumptions no longer valid.



Industry Studies



- **Four, \$1M contracts**
 - 6-month studies
 - 1st half – broad trade study, innovative ideas.
 - 2nd half – refine single concept (JPL's choice)
 - Implementation
 - Technology needs
 - Flight validation needs
- **Examine - full scope of a 2011 Mars Sample Return mission**
 - Given sample requirements, landing location guidelines, planetary protection constraints, program constraints.
 - Assumed a US Only implementation, that can be massaged later.



Study Objectives

- **Obtain information to aid in establishing a reference technical approach for a sample return mission.**
- **Obtain planning reference information on:**
 - projected mission costs and cost drivers
 - high risk areas
 - required technology developments
 - needs for flight validations
- **Aid in establishing validation requirements on missions flying before a sample return mission is conducted.**



Study Teams

The four teams led by:

Ball Aerospace & Technologies Corporation

Boulder, Colo.

The Boeing Company

Huntington Beach, Calif.

Lockheed Martin Corporation

Denver, Colo.

TRW

Redondo Beach, Calif.



Industry and Academia engaged



TRW

LOCKHEED MARTIN



ASU ARIZONA STATE UNIVERSITY



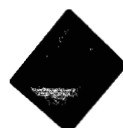
MICROCOSM, Inc.
Space Mission Engineering



SpaceDev



Thiokol Propulsion
an Alcoa business



FORTUNE EIGHT
Aerospace Industries, Inc.
International Technical Services



Carnegie Mellon



DELTA VELOCITY



PHYSICAL SCIENCES INC.





Ground Rules

- **Intent – each study to generate an independent fresh view of MSR.**
 - Isolation from other MSR activities (MPSET, Etc)
 - Isolation from the other 3 teams
 - Single contact for info/support from NASA community
 - Limited to technology, NASA infrastructure, celestial mechanics.
- **Guidelines and Constraints**
 - Mars Program Architecture and funding constraints
 - Science Requirements
 - Planetary Protection Constraints (backward and forward)
 - Technology Readiness Requirements
 - Premium on safe landing



Baseline Science Objectives



- **Mission Objective - return Martian Sample to surface of the Earth - Launch in 2011 opportunity**
 - Mass of sample > 500 gm
 - Sample includes rock, regolith, atmosphere
 - Sample diversity assured by surface mobility - collection > 1 km radial from landing site (few months excursion)
 - Includes a sample from depth of > 2 m
 - Landing location accessibility: within $\pm 15^\circ$ Lat and < +1.5 km altitude (with respect to the MGS (MOLA-based) mean reference)
 - Landing accuracy < 10 km



Phase-1 SOW

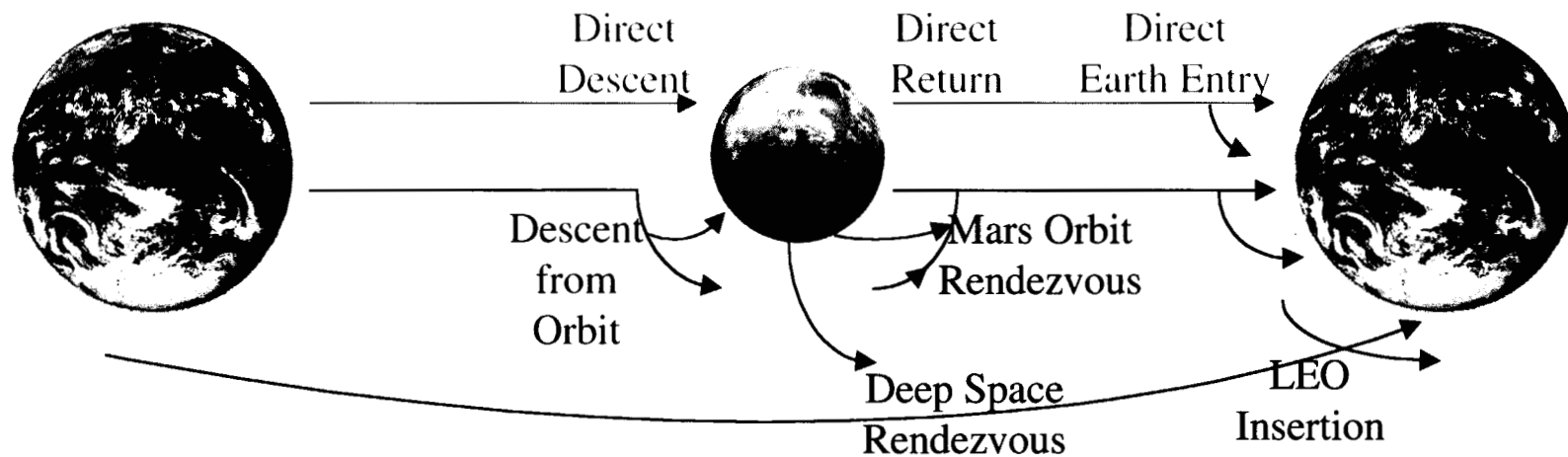
- **Conduct trade studies across a range of viable technical approaches.**
- **Develop a “preferred” mission concept which meets the baseline objectives.**
- **Develop at least one alternative mission concept within the objective space bracketed by**

[baseline - → baseline → baseline +]

[\$1B → \$2B]



Example MSR Trade Space





Study Trades (as a minimum)



Launch

- Separate spacecraft launches on expendable launch vehicles
- Combined spacecraft launch on expendable launch vehicle
- Shuttle launches with spacecraft assembly on-orbit

Earth-to-Mars Cruise and Approach

- Earth-to-Mars transit
 - Ballistic flight
 - Low thrust flight
- Approach navigation
 - Radio data types
 - Optical data

Mars Orbit

- Orbit insertion
 - Chemical propulsion
 - Aerobraking
 - Aerocapture

Mars Atmosphere Entry, Descent, and Landing

- Lander entry
 - Lander entry direct from cruise
 - Lander entry from Mars orbit
- Entry/Descent techn
 - Entry aeroshell shape
 - Chutes
 - Powered descent
- Landing techniques
 - Hazard detection and avoidance
 - Impact attenuation

On the Surface

- Sample collection
 - Mobility
 - Sub-surface
 - Collection options
- Sample handling
 - Number of exchanges
 - Risks
 - Contamination chain

- Communications requirements and infrastructure
 - Post sample collection long surface life, lateral and subsurface range

Ascent from Mars Surface

- Return profile
 - Mars rendezvous
 - Deep Space Rend.
 - Direct return to Earth
 - Solid propellant
- Mars Ascent Vehicle
 - Unguided
 - Liquid propellant
 - Cryogenic propellant
 - ISPP
 - Guided
 - On rover
 - On lander
- Options for ground asset survival after MAV launch

Mars-to-Earth Cruise

- Mars-to-Earth transit
 - Ballistic flight
 - Low thrust flight

Return to Earth

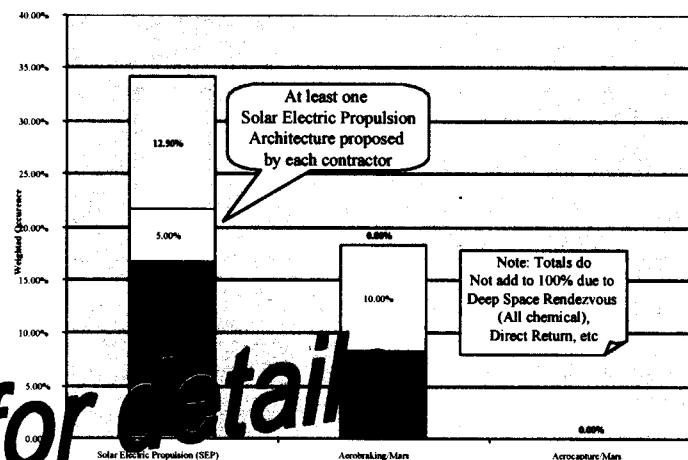
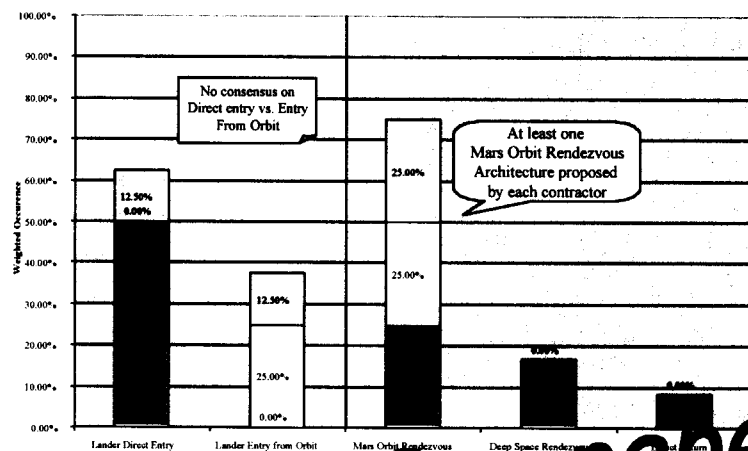
- Earth Atmosphere Entry Capsule
 - Direct entry from cruise trajectory
 - Entry from Earth orbit
- Shuttle rendezvous

Program Phasing

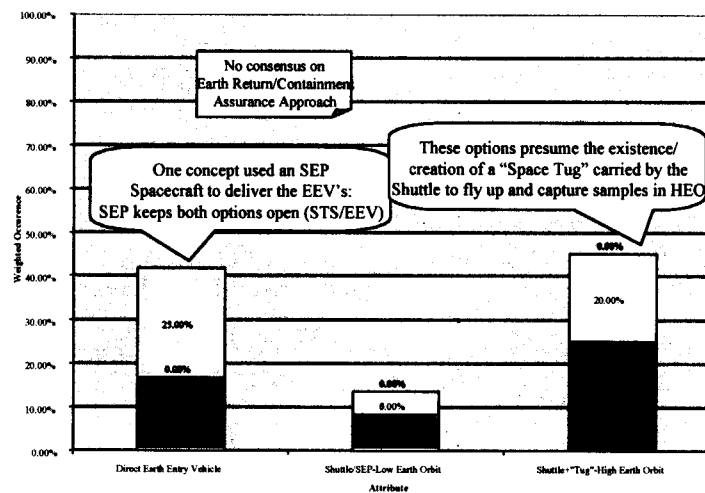
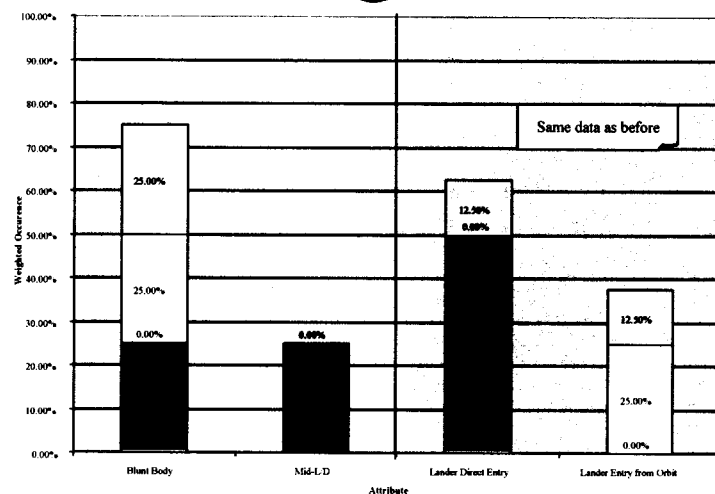
- Launches in same opportunity
- Launches in separate opportunities



Phase-1 Results Themes



See paper for detail





Phase-2



- Study of single concept (as directed by JPL) in more detail, including
 - a project development cost estimate (including LV's)
 - a listing of needed technology advances
 - recommendations for flight validations
- Concepts selection
 - Based on balanced criteria
 - Performance relative to sample return objectives
 - Life cycle costs
 - Risks of technology readiness
 - Technology heritage provided to future Mars missions
 - Consistent with what the team Proposed in Phase-1
 - Based on guidance from the multi-agency/multinational Mars Program System Engineering Team (MPSET).
 - Moderate mission set, thought to be less than \$2B.



Criteria for Mission Concept Selection



Balance between:

- Performance relative to sample return objectives
- Life cycle costs
- In-flight risks and overall reliability
- Risks of technology readiness
- Technology heritage provided to future Mars missions



3/10/02

Solar System Exploration Advanced Studies Office

RLM-15



Phase 2 Concepts-After Phase 2



	Ball	Boeing	LMA	TRW
# of Launches	1	1	1 / 1 1 1	1
ΔV for Earth-Mars Cruise	Chemical	SEP ERV, Chemical Lander	Chemical	SEP
Orbiter Capture	Chemical with aerobraking	SEP	Chemical	SEP
Mars Lander EDL	Direct	Direct	Direct	Two Landers from orbit
Surface Ops	2 x (Lander + MAV + drill, RPS rover)	2 x (Lander + MAV, RPS rover + drill)	Lander + MAV + drill, MER rover	2 x (Lander + MAV + drill, rover)
Mars Orbit Rendezvous	LMO	LMO	Libration Pt Rend / LMO	LMO
Mars-Earth Cruise	Chemical	SEP	Chemical	SEP
Earth Orbit Insertion?	Yes, SEP, rendezvous with separate launch EOV, 2 sample canisters returned	Yes, spiral to LEO, shuttle mission to return, 2 sample canisters returned	No, Direct	No, Direct entry, 2 sample canisters returned on two separate EEVs



Follow-up w/ Internal Study



- Utilized JPL's Advanced Mission Design Team (Team-X).



Team-X Architectures Studied



# of Launches	TeamX Option A	TeamX Option B
ΔV for E-M Crs # of veh E-M	Chemical Two	Chemical Three
Orbiter Capture	Chemical with aerobraking	Chemical with aerobraking
Mars Lander EDL	Indirect	Direct
Surface Ops	Lander + MAV + Drill, MER rover	2 x (Lander + MAV + drill, MER rover)
Mars Orbit Rendezvous	LMO	LMO
M-E Cruise	Chemical	Chemical
Direct or Earth Orbit Insertion (EOI)	Direct via one EEV with one sample canister	Direct, 2 EEV's with one OS each

See paper



Also in paper



- **Overview of Mars Exploration Program**
- **Extended bibliography on Mars Sample Return**



In Summary

- **Got a tremendous amount of work done.**
- **NASA and JPL objectives were met.**
- **We understand Mars Sample Return better than we ever have.**
- **We have a much better idea of what the technology & validation needs are leading to Mars Sample Return.**



Backup Slides

3/10/02

Solar System Exploration Advanced Studies Office

RLM-21